15th International Command & Control Research & Technology Symposium

Command & Control in Virtual Environments:

Designing a Virtual Environment for Experimentation

Topic: Topic 3, Information Sharing and Collaboration Processes and Behaviors

Ken Hudson, Loyalist College*

Mark E. Nissen, US Naval Postgraduate School

* Point of contact

Ken Hudson
Virtual World Design Centre, Loyalist College

KenHudson@infinitespaces.ca
613-969-1913 x2435

ABSTRACT

Research in command and control is advancing rapidly through a campaign of laboratory experimentation using the ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust) multiplayer online counterterrorism intelligence game. In most ELICIT experiments, participants play the game through a Web interface and interact with one another solely through textual information exchange. This mirrors in large part the network-centric environment associated with most counterterrorism intelligence work in practice. However, we argue that a more immersive virtual environment offers potential to improve performance. The research described in this article addresses the preliminary design and prototyping of an immersive and dynamic, virtual environment for ELICIT experimentation, in which participants play the game through avatars representing them. We summarize a number of alternate virtual environment platforms available to researchers for work such as this, and we explain the rationale for the specific environment selected for this project. Additionally, we describe the prototypical design strategies for adapting game play into virtual environments and characterize preliminary case examples to understand the differences and potential benefits of adapting ELICIT game play. This research lays a foundation for moving experimentation into immersive virtual environments.

Keywords: avatar, collaboration, ELICIT, experimentation, virtual environment

Acknowledgements: The research described in this article was funded in part by the Command and Control Research Program through the Center for Edge Power at the Naval Postgraduate School.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **JUN 2010**	2. REPORT TYPE	3. DATES COVERED **00-00-2010 to 00-00-2010**
4. TITLE AND SUBTITLE **Command & Control in Virtual Environments: Designing a Virtual Environment for Experimentation**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Postgraduate School,Center for Edge Power,589 Dyer Road,Monterey,CA,93943**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Proceedings of the 15th International Command & Control Research & Technology Symposium, Santa Monica, CA (June 2010).

14. ABSTRACT
Research in command and control is advancing rapidly through a campaign of laboratory experimentation using the ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust) multiplayer online counterterrorism intelligence game. In most ELICIT experiments, participants play the game through a Web interface and interact with one another solely through textual information exchange. This mirrors in large part the network-centric environment associated with most counterterrorism intelligence work in practice. However, we argue that a more immersive virtual environment offers potential to improve performance. The research described in this article addresses the preliminary design and prototyping of an immersive and dynamic, virtual environment for ELICIT experimentation, in which participants play the game through avatars representing them. We summarize a number of alternate virtual environment platforms available to researchers for work such as this, and we explain the rationale for the specific environment selected for this project. Additionally, we describe the prototypical design strategies for adapting game play into virtual environments and characterize preliminary case examples to understand the differences and potential benefits of adapting ELICIT game play. This research lays a foundation for moving experimentation into immersive virtual environments.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**20**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

INTRODUCTION

Modern military organizations have adapted and evolved over many centuries and millennia, respectively. Hierarchical command and control (C2) organizations in particular have been refined longitudinally (e.g., through iterative combat, training and doctrinal development) to become very reliable and effective at the missions they were designed to accomplish. However, recent research suggests that the Hierarchy may not represent the best organizational approach to C2 in all circumstances (Nissen, 2005), particularly where the environment is unfamiliar or dynamic. Indeed, alternate, more flexible C2 organizational approaches such as the Edge have been proposed (Alberts & Hayes, 2003) to overcome Hierarchy limitations, but the same recent research suggests that the Edge may not represent the best organizational approach to C2 in all circumstances either, particularly where the environment is familiar and stable.

Of course, the Hierarchy and Edge both represent organizational archetypes (Orr & Nissen, 2006), each of which offers considerable latitude in terms of detailed organizational design and customization. For instance, recent research demonstrates further how the performance of both Hierarchy and Edge organizations is sensitive to factors such as network infrastructure, professional competency and other factors that can be affected through leadership, management and investment (Gateau, Leweling, Looney, & Nissen, 2007). With incessant advances in information technology (IT) that appear to be continuing, one may be able to overcome the limitations inherent in Hierarchy, Edge or other organizations or even enable such organizations to adapt—through IT—to shifting conditions.

This notion is fundamental to Network Centric Operations (NCO), where people and organizations operate principally in network-enabled virtual environments as opposed to their physical counterparts. Unfortunately, empirical evidence to support the asserted superiority of NCO remains sparse, and the capability enhancing properties of virtual environments remain more in the domain of lore than empirical assessment. To remedy such empirical sparseness, we continue a campaign of laboratory experimentation using the ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust) multiplayer online counterterrorism intelligence game to understand the comparative advantages and disadvantages of alternate C2 approaches, organizational forms, technologies and like aspects across a range of current and anticipated operational environments. Indeed, drawing from substantial research in modeling and virtual environments, we argue that a more immersive virtual environment offers potential to improve performance.

The research described in this article addresses the preliminary design and prototyping of an immersive and dynamic, virtual environment for ELICIT experimentation, in which participants play the game through avatars representing them. In the balance of this article, we summarize a number of alternate virtual environment platforms available to researchers for work such as this, and we explain the rationale for the specific environment selected for this project. Additionally, we describe the prototypical design strategies for adapting game play into virtual environments and characterize preliminary case examples to understand the differences and potential benefits of adapting ELICIT game play. This research lays a foundation for moving experimentation into immersive virtual environments.

BACKGROUND

Virtual environments are dynamic and customizable platforms for interaction. They present “a synchronous, persistent network of people, represented as avatars, facilitated by networked computers” (Bell, 2008). They allow users to design and implement contextually relevant spaces for business, education, research, as well as for socializing.

While akin to computer based game environments and online games, virtual environments allow for a flexibility of usage that sets them apart from previous analogous iterations. The similarity between these forms would lead one to believe that virtual worlds are a type of open-ended game, whereas researchers suggest that online game themselves are a fixed type of virtual world (Scroeder, 2008).

Only a short time ago, to develop an immersive custom environment would have been time consuming and expensive. As these platforms multiply, the use cost has diminished, and the flexibility has increased, making this an ideal time to pursue research requiring a virtual environment.

In considering the appropriate virtual environment for research, it is important to ensure that the selected platform is sustainable and not in any danger of going out of business. With a dynamic new marketplace for “desk-top virtual worlds” (Hudson, Wood, Wetsch, & Solomon, 2009), come many different platforms, some of which will inevitably close. Virtual environments like Metaplace, seen as early competition to market giants like Second Life, have recently folded. The market for virtual world platforms continues to augment, change, with new players entering all the time. It is therefore important to consider the persistence of any platform chosen for this experimentation.

While there are dozens of virtual world platforms from which to choose (Robbins, 2010), many of these virtual environments are more akin to online games in that they are themed and defined. Thus the list of practical platforms available for fully customized environments is greatly reduced. The adaptation of ELICIT into a virtual environment has very specific project parameters that again focus the type of virtual world platform that would be most suitable.

The ELICIT game-play requires a very basic virtual environment set-up, free of extraneous elements, but also highly customizable in order to adapt to various experimental aims. The 3D virtual environment needs to function in the same way that the real world 2D computer-based ELICIT game-play does, expect for the addition of the interactive spatial element to which this research is focused. Players in the virtual environment need to be able to receive, read, and evaluate factoid clues that are communicated in a text-only format. They need to be able to then share what are deemed relevant factoids with other players, and they need to be able to submit their answers to the challenge when they believe they have solved it.

The additional component to the ELICIT game-play experience in a virtual environment is the ability for participants to interact with one another around the game context. This could involve a range of interactivity from having a common “bulletin board” to view games factoids, to inter-personal discussions surrounding the factoids, to be determined by specific experimental

constraints. Whatever the level of interaction for each experiment, it is crucial that the ability to communicate with one another be included in the virtual environment set-up.

In choosing the most suitable platform for adapting ELICIT, a comparison of leading virtual worlds was conducted examining the key features for each product that are salient to the research. What is clear is that at the top strata of virtual platforms there is tremendous overlap between the various providers. This research focuses on four established virtual world platforms and examines their offered features in light of several key experimental criteria:

1) Accessibility: Virtual environment platform must be universally accessible between operating systems. The environment must be intuitive in terms of its usage, reducing to the bare minimum the training load for all participants.
2) Communication: Virtual world platform must allow for both text and voice communication. This communication apparatus must be straightforward to learn and simple to use.
3) ELICIT specific requirements: ELICIT game-play is a proctored clue-based game that collects information about game-play in a database so that researchers may examine statistical records of each game round. Currently the game functions are handled by JavaScript, so ideally, the virtual environment will support the inclusion of JavaScript without significant re-coding of the environment.
4) Customization: The virtual environment must support complete customization of spatial aspects. This customization can preferably be done in an expedient manner.

Out of the dozens of virtual environment platforms in existence today, a short-list of suitable products has been determined by examining the range of platforms in lieu of the preceding criteria. While these platforms contain most of the required features, some are stronger than others in certain aspects. For the preliminary research understanding the effects of the environment on ELICIT game-play, all of the following platforms have the core requirements to proceed with the research:

Second Life/ OpenSim

A popular leader in the desktop virtual worlds revolution, for many Second Life has become synonymous with virtual environments. With built-in building tools, Second life offers a high degree of design flexibility, which enables designers to rapidly prototype environments and adapt them quickly within the world. OpenSim is an open-source community built around upon the Second Life platform, while maintaining the look, feel, and functionality of the parent platform. The basic communication requirements for the ELICIT experiments are included with the Second Life platforms. However, until recently, one potential obstacle to full virtual integration of ELICIT was the lack of JavaScript functionality natively present in Second Life and the Opensim platform. With the recent release of Second Life Viewer 2.0, which contains a complete range of media features and web functionality this obstacle has been, for the most part, averted. One appealing aspect of the Second Life platforms is the communal element, which allows researchers to solicit input and showcase the experimental environment readily with colleagues in education and government. While some coding work is still necessary to complete integration with Viewer 2.0, as a starting point for designing the experimental space, Second Life

offers the ability to quickly construct, edit, and deploy assets within the space itself, which is crucial in the early design phase. See screenshot in **Figure 1**.

Figure 1 Second Life and OpenSim

Teleplace

Teleplace (formerly Qwak) offers a very basic virtual environment that could potentially be used for ELICIT experimentation. While it contains less broad functionality and naturalistic elements that are native to the Second Life platforms, many of these natural elements may be considered extraneous to the ELICIT experimental design. The spaces within Teleplace are interior only spaces, with no access to natural landscapes. In the early phase of the project development, this is not an issue. However, as the project proceeds, it is possible that researchers may want to employ exterior spaces as part of the research. As with the original Second Life viewer, Teleplace does not offer any JavaScript functionality, and, unlike the OpenSim aspect of Second Life, Teleplace does not provide the openness of code to all this addition. That said, the Python scripting language is supported by Teleplace, which would allow developers to recreate the scripted content of ELICIT within this platform. However, significant development time would be required to achieve that end. Furthermore, while Teleplace allows for customized environments, these modeled structures must be developed outside the platform using professional modeling tools, therefore eliminating the ability for rapid prototyping of designs. The designs, that are imported, however, would be of fine quality. The difficulty at the early phase of this project is that significant reworking of these models would be required to make even the smallest changes to the experimental spaces. See screenshot in **Figure 2**.

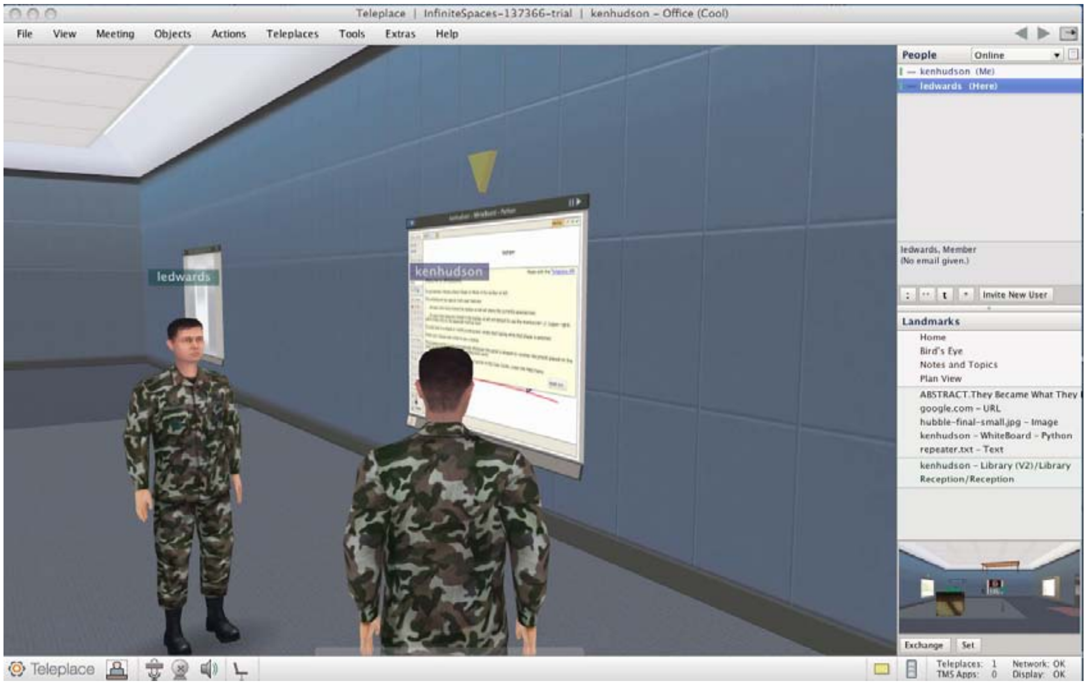

Figure 2 Teleplace

O.L.I.V.E.

OLIVE (On-Line Interactive Virtual Environment) by Forterra is one of the most versatile and rigorous of the various virtual world platforms examined. Like Second Life, OLIVE is a broad environmental platform, with a native naturalistic environment that allows for both interior and exterior spaces. However, like Teleplace, OLIVE requires that modeled structures and spaces be created outside of the platform and imported. As such, this limits the ability to adapt and modify models quickly according to experimental specifications. The functionality of OLIVE allows for all the basic communication and person-to-person interaction as in both Second Life and Teleplace. One key advantage that OLIVE offers which is not available in many of the other platforms is JavaScript support. As a result, researchers could seemingly utilize the current coded ELICIT product within OLIVE without rewriting or adapting the coding to a different language. This could be a great resource saver, in that time and money would need not be invested in recreating the ELICIT functionality within the virtual environment. Instead researchers would be able to simply bring that functionality into the environment itself. While not suited to the rapid prototyping of the design in the early phases of the project, OLIVE could potentially be very useful in later fully immersive ELICIT experiments. See screenshot in **Figure 3**.

Figure 3 O.L.I.V.E.

Protosphere

Protosphere is one of the most widely used enterprise level virtual world platforms, especially for distributed business collaboration. Like Teleplace, Protosphere focuses on interior meeting and training spaces, rather than on exterior environments. However, unlike Teleplace, there are exterior spaces that can be viewed through windows, creating a realistic office setting. Like the OLIVE and Teleplace platforms, specific models may be created in external programs and imported to customize any space. However, as with the other platforms (except Second Life/OpenSim), this restricts the speed with which elements may be changed or adapted. Similar to the OLIVE platform, Protosphere enables the use and sharing of any document or application that is able to run on the users' desktop environment within the virtual space. The ability to natively run ELICIT within Protosphere without adapting the code is a significant benefit of the platform. Functionally, Protosphere offers all of the communications tools required to use ELICIT in the virtual space. Unlike the other platforms reviewed which are all able to run on either a Windows or Macintosh operating system, Protosphere is only available for Windows OS at this time. See screenshot in **Figure 4**.

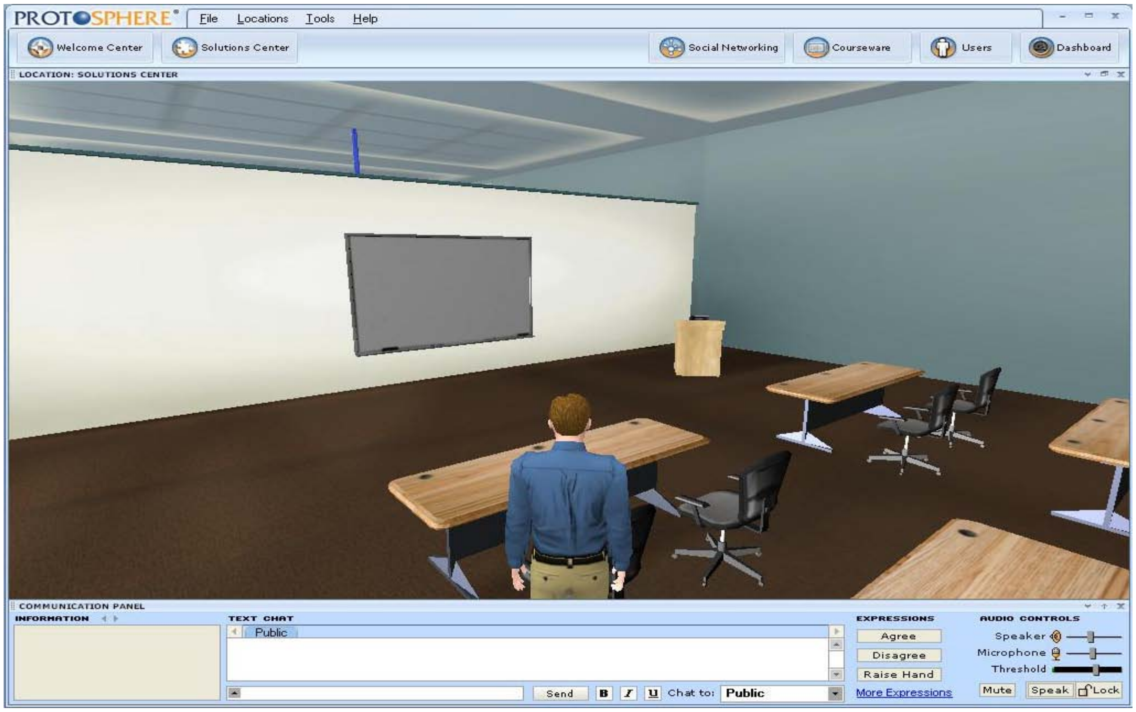

Figure 4 Protosphere

ELICIT USE CASE DESIGN IMPLICATIONS

In this section, we draw heavily but briefly from (Leweling & Nissen, 2007; Powley & Nissen, 2009) to summarize the current ELICIT interface and game play. This helps to establish a use case and set of design specifications for the development of an immersive environment for ELICIT: succinctly, we wish to develop a virtual environment that emulates the current ELICIT environment as closely as possible with the exception of people playing the game through avatars instead of the current textual interface. We begin by describing this task environment and then outline the participants, groups, protocols, controls, manipulations and measurements used typically for experimentation via ELICIT. We close this section with a summary of design implications.

Task Environment

The task requires a team of participants performing the roles of intelligence analysts to collaborate and identify a fictitious and stylized terrorist plot. The fictitious terrorist plot is described through a set of informational clues called "factoids" that have been developed systematically. The game's design is similar to the Parker Brothers' board game "Clue" in that it requires each player to analyze clues and combine assessments with other players to identify key aspects of the fictitious plot. Each factoid describes some aspect of the plot, but none is sufficient

to answer all of the pertinent questions (i.e., Who will execute the attack? What is the target to be attacked? Where will the attack take place? When will the attack take place?).

The factoids are distributed among the players in a series of steps: each player receives two clues initially, followed by one after five minutes of play and another after ten minutes have elapsed. The factoid distribution is designed so that no single player can solve the problem individually and that the team of players cannot solve the problem until after the final distribution. In other words, the players must collaborate to solve the problem, and they are required to do so for a minimum of ten minutes. Evidence from previous experiments (e.g., (Parity Communications Inc., 2006) suggests that play requires substantially more time (e.g., an hour or more).

Participants play the game in one or two modes. 1) For the virtual environment, they play via ELICIT client applications on separate computer workstations linked to a Web game server. Each subject has access to a set of five functions supported by the client application: 1) List, 2) Post, 3) Pull, 4) Share, and 5) Identify. After the game has completed, the administrator ends the simulation from the server application. The ELICIT application captures time-stamped interactions (e.g., Pose, Pull, Identify, List functions) including, for instance, when and which factoids are distributed to each player, when and which factoids are posted to which common screens, when and which common screens are viewed by each player, when and which factoids are shared between each player, and the time stamped results of each player's Identify attempt (i.e., to identify the who, what, where and when). 2) For the physical environment, they play through face-to-face interaction in rooms equipped with tables and white boards. Factoids are time stamped and distributed to the players on pieces of paper, and paper "postcards" are time stamped and used to collect players' Identify attempts. We do not attempt to log or time stamp players' other information sharing and processing activities.

The game requires considerable cognitive and collaborative effort to play well (i.e., identify the pertinent details of a terrorist plot), but experience indicates that such effort is within the capabilities of many people and groups.

Participants

Participants for ELICIT experiments come from a broad variety of backgrounds (e.g., ranging from undergraduate students to professional intelligence analysts). In most studies, participants are organized hierarchically as delineated in Figure 5. Such organization stratifies them into three functional levels. The Senior Leader is responsible for the intelligence organization as a whole and has four Team Leaders (middle managers) reporting directly. Each team leader in turn has three Team Members (Operators) reporting directly and is responsible for one set of details associated with the terrorist plot. For instance, Team Leader (Who) and his or her team are responsible for the "who" details (e.g., which terrorist organization is involved) of the plot, Team Leader (What) and his or her team are responsible for the "what" details (e.g., what the likely target is), and so forth for "where" and "when." Participants are assigned randomly to these roles as a general rule.

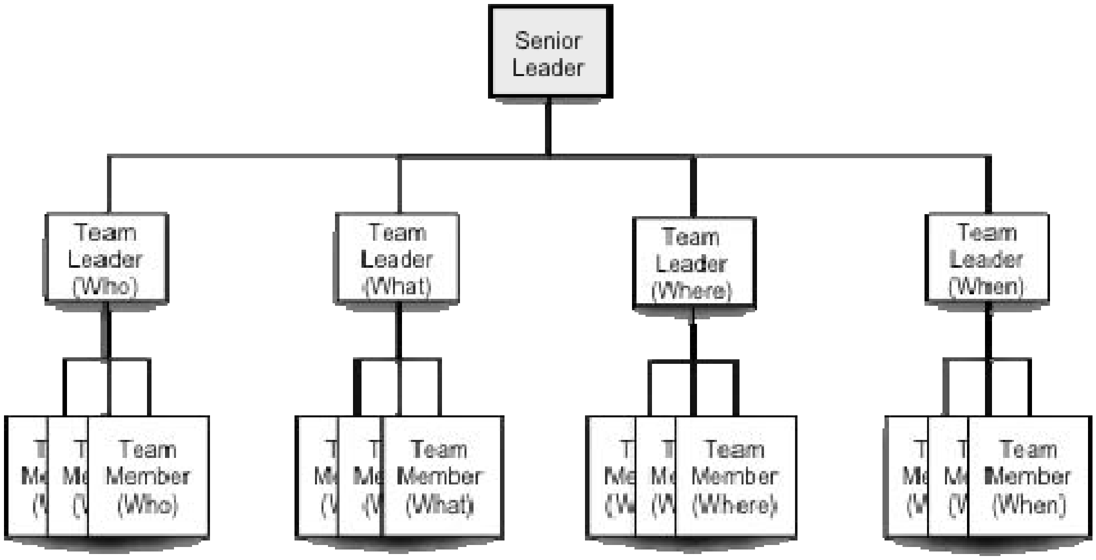

Figure 5 Hierarchical Organization

Treatment Groups

Participants are assigned to play in groups of 17 members. However, many experiments manipulate the organizational structure to compare efficacy of the Hierarchy (i.e., as most intelligence groups are organized currently) with alternate structures (esp. the Edge (Alberts & Hayes, 2003). As suggested above, many other experiment treatments (e.g., alternate communication technologies (Thunholm et al., 2009), knowledge vs. information flows (Leweling & Nissen, 2007), trust (Powley & Nissen, 2009), textual vs. physical interactions (Wynn, Ruddy, & Nissen, 2010), others) are assessed through ELICIT experiments, and participants are assigned generally to different treatment groups according to each specific experiment design.

Protocols. Protocols share many similarities across ELICIT experiments. Generally, participants report to a networked classroom on their assigned day for the experiment. Once seated, participants are allotted ten minutes or so to read a set of instructions pertaining to both the experiment and the ELICIT environment; they are encouraged to ask questions about the experimental settings and environment. Once participants read the instructions, in many studies they have another ten minutes or so to discuss their approach to the problem-solving scenario with others in their group and take a short break before beginning.

Once the game begins, each participant receives unique factoids in three phases: 1) two factoids initially when the game begins, 2) one after five minutes, and 3) one at the ten-minute mark. Role-specific factoids are distributed automatically by ELICIT and in a manner ensuring: a) that no player can solve the plot alone, and b) that the plot cannot be solved until all factoids

have been distributed. Factoids are time stamped and appear automatically on players' ELICIT screens, after which they can be posted, pulled and shared. As noted above, all Post, Pull, Share and Identify actions are time stamped and logged by the game server.

In most experiments, participants communicate with one another during game play using only the computer-network capabilities supported by ELICIT (esp. Post, Pull and Share); no verbal communication is allowed. Although some prior experiments incorporate chat and like technologies as manipulations (Thunholm et al., 2009), such technologies are not permitted in most study protocols.

Each player is assigned, randomly in most studies, a pseudonym associated with his or her role in the game, and to conceal players' identities in previous experiments, their pseudonyms are not to be revealed. This proves to be an unenforceable protocol in many prior experiments, however, as players are situated often in the same room and able to ascertain one another's pseudonyms.

Additionally, the ELICIT software limits participants' Post (i.e., sharing factoids with others) and Pull (accessing factoids posted by others) access to specific common screens within the Hierarchy case. Specifically, those players in the "who" group, for instance, are allowed to Post to and Pull from only one of the four common screens (i.e., the "who" screen) noted above. The only exception applies to the Senior Leader, who has post-pull access to all four common screens. This restriction is relaxed in most experiments examining the effects of alternate organizational forms (e.g., Edge).

Also, most experiments enable every player to share factoids with any other player, regardless of team assignment. This appears to conflict with the post and pull restrictions from above and to mitigate the effects of hierarchical organization. In some experiments (Bergin et al., 2010), however, factoid sharing conforms to the same restrictions set up for post and pull (e.g., within-group only): Operators are permitted to share only with members of their own teams, and Team Leaders are permitted to share only with Operators on their respective teams in addition to the Senior Leader. Further, the Senior Leader communicates only with Team Leaders. This reinforces hierarchical communication and chain of command and provides greater contrast with the Edge and other organizational approaches.

The simulation ends after approximately 45-60 minutes. All players are given the option to Identify the plot details if they have not done so already. In many experiments, players are instructed to Identify only once during game play, whereas in others multiple Identify attempts are permitted. In either case participants are incentivized both to solve the plot individually as well as to collaborate so that others on the team (esp. the Senior Leader) solve the plot quickly and accurately.

Measurements

Measurements of dependent variables vary, but many follow variations of a two-factor the scheme (Leweling & Nissen, 2007). For instance, one can operationalize performance as a two-dimensional dependent variable comprised of: 1) *speed* (i.e., time to identify plot details

correctly) and 2) *accuracy* (i.e., correct identification of plot details). These dependent measures are informed by literature in the psychological and organizational domains that suggest a trade-off exists between time and accuracy in tasks requiring high cognition and/or advanced motor skills (e.g., see (Beersma et al., 2003; Elliott, Helsen, & Chua, 2001; Guzzo & Dickson, 1996; Meyer, Irwin, Osman, & Kounios, 1998; Plamondon & Alimi, 1997; Rogers & Monsell, 1995) at both the individual and team/group levels of analysis.

In the first component, speed pertains to how long it takes a participant to submit his or her identification of the terrorist plot details. For ease of comparison, the scale for this speed measurement is normalized often to a 0-1 scale, with 1 being more desirable (i.e., faster). Measuring and normalizing time is straightforward, as the time for each participant's identification is logged to the nearest second by the software. Specifically, each participant's elapsed time is recorded when he or she uses ELICIT to Identify the plot. To construct a scale in which faster speeds (i.e., shorter times to Identify) result in larger values, a baseline time is established as the maximum time required for the slowest of all participants (i.e., 3000 seconds in this experiment). Each participant's time to identify is related to this baseline and normalized to produce a scaled score according to the formula: speed = (3000 – time) / 3000; that is, an individual participant's time (say, for example, 2375 seconds) would be converted to a speed score as: speed = (3000 – 2375) / 3000 = 0.2083. All participants' times are converted to speed scores in this same manner and using this same baseline.

The second component of performance, accuracy, refers to the quality of the identification of the impending terrorist attack (i.e., Who, What, Where, and When). Each participant's Identify action is scored with a value of 1 for each correct answer to the Who, What and Where aspect of the solution. Note, however, that the When aspect of the solution includes three components (i.e., Month, Day, and Time). In order to avoid weighting this aspect more heavily than the other three, each participant's Identify action is scored with a value of 1/3 for each correct answer. The resulting sum is divided by four to construct a [0-1] scale; that is, an individual participant's Identify (say, for example, identifies the Who, What and Where aspects correctly but is correct only on the day and not the month or time components of the When aspect) would be converted to an accuracy score as: accuracy = (1 + 1 + 1 + 1/3) / 4 = 0.83.

Design Implications

With this description we have the basis of a use case for ELICIT. The central design task requires preserving as much of the typical ELICIT play as possible while exploring the implications of such play being performed in immersive virtual environments. In terms of virtual environments, most of the previous research has focused on the experimental response to human representation (avatar) and its activity, and not on the environment itself. This research aims to understand what impact, if any, the environment specifically has on participants that could potentially improve performance within ELICIT.

Currently ELICIT is a solitary activity, with participants separated in a manner that is analogous with real world intelligence sharing. In designing an ELICIT experience where participants may have access to one another, share a common space, or discuss various factoids,

this research seeks to understand how performance may be enhanced by this collective environment.

By adapting ELICIT for play within a virtual environment, two new elements of the experience are being added:

1) The ELICIT game-play will not take place in an environment as a discernable place.
2) Participants experience themselves as present within that space, and co-present with the other participants.

This research seeks to understand how the addition of a spatial dimension impacts the performance of participants within the game, and whether it supports more successful game-play, or whether it detracts from the success of participants.

PRELIMINARY VIRTUAL ENVIRONMENT DESIGN AND PROTOTYPE

Environments are by definition complex. They envelope and surround us, and even the most simplistic environment is filled with a staggering range of elements and stimuli. This is true whether that environment is physical or virtual, as they both contain aspects that have varying types of emotional valence. In order to determine the affective charge of each environmental element in the adaptation of ELICIT, it is important to begin this experimental process with a neutrally toned environment from which to build on.

The first step in this process is to limit extraneous elements from the preliminary design. To that end, designers are utilizing the International Affective Picture System (IAPS) in order to understand the emotional valences of various images, and to use that catalogue of affects to determine a properly neutral environmental design for the ELICIT experimentation to take place in.

The IAPS images are a series of emotionally charged representations that are used in various types of experiments to add a pre-determined affective tone to the content (Lang, Bradley, & Cuthbert, 2008). Researchers already understand the potency of this imagery, noting that a single valence determined image can "put someone in an emotional state lasting several minutes" (Wilson, 2005).

While three-dimensional virtual environments seem like a distant cousin to static photographic images, it should be noted that virtual platforms that are deemed 3D are in fact 2D environments where the illusion of three-dimensions is created by placing the participant in a surrounded landscape and then allowing the participant to navigate this all 360 degrees of this space. This effectively creates 3D space, but only as perceived by the user. In fact, the space is projected on a flat panel computer monitor, and is no more 3D than the current ELICIT game-play. However, from an experiential point of view, this forced 3D perspective is enough to give the participant the sense that they are operating in a realistic space. See screenshot in Figure 6.

Figure 6 Neutral Space Prototype

There is an interesting and unexplored analogy between IAPS affectively charged imagery and its impact on behavior, and the visual stimuli of virtual environments. Participants in these worlds are not simply being displayed or flashed an affectively biased image, but are in fact deeply immersed and emotionally involved with the environment itself. That environment is constructed by a series of two-dimensional textures to create the optical illusion of three-dimensional space. Therefore it is believe that a careful study of the affective quality of the IAPS imagery will lead designers to understand how to develop virtual environments with a specific emotional tonus.

This stimuli classification system provides designers with a range of imagery that falls into broad categories like positive stimuli, negative stimuli, and neutral stimuli. By analyzing the imagistic components of IAPS, virtual environment designers are able to include aspects and elements of the design to achieve a neutral environment for experimentation. Furthermore, this design process will help develop a “pattern language” of virtual environment design. “A pattern is an instruction, which shows how this spatial configuration can be used, over and over again, to resolve the given system of forces, wherever the context makes it relevant" (Alexander, 1977).

Out of this work, a lexicon of imagery and an inventory of archetypal stimuli will emerge that can be employed in future virtual environment designs to facilitate various experimental parameters as well as influence the experimentation with specific emotional valences. Researchers in the present study of ELICIT game-play will understand which kinds of environmental stimuli in the virtual environment support enhanced performance and which detract from it.

Aside from the affective components of the design that an analysis of IAPS will reveal, there are certain obvious elements that are built into the initial design of the ELICIT game space that will support its neutral valence. These aspects include:

1) Creation of interior only spaces free from the complexity of the natural world including sunlight, plants, landscape variances (water to land), clouds, and all other natural elements that do not support the experimental objectives.
2) Subtle texturing of spaces so as not to overtly determine building materials. As texture is one aspect of imagery that impacts emotional response, designers need to be aware not to overly texture the spaces. Therefore building elements that reduce specific reference to their materials, for example dry wall rather than bricks, linoleum flooring rather than hard wood, and tightly woven fabric textures rather than broad weaves, need to be employed to reduce emotional stimuli.
3) Constant ambient lighting will also create a comfortable space for visual data without dramatic inputs from spot lighting or the natural light occurring through windows.
4) Narrow range of inputs and the exclusion of distracting elements will help the environment focus participants on the task oriented experimentation, rather than on the environmental elements contained therein.

Figure 7 Realistic Texturing Changes Emotional Tone

While this environment will not be a distinguishable real place, it is a place nonetheless. It is intended that the experimental virtual environment will feel like a real place to the participants, while not carrying any overtly determined emotional charge. Participants need feel they are "somewhere," that place must function to support game-play, and the participants must also experience co-presence in that space with the other participants. See screenshot in Figure 7.

The "somewhere" that researchers have decided on as a starting environment for experimentation is based on a physical space previously utilized for ELICIT experiments. While not a specific place per se, this hybrid environment, based on a real physical room, connects in a meaningful way to the previous ELICIT runs. This hybrid space follows the criteria outlined above for the specific qualities of a neutral space. However, it is believed that because this hybrid environment is closely related to rooms used in previous experiments, it will allow researchers a more precise point of comparison when analyzing results from the virtual space and from the physical lab. See screenshot in Figure 8.

Figure 8 Hybrid room based on physical experimentation space

CONCLUSION

Research in command and control is advancing rapidly through a campaign of laboratory experimentation using the ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust) multiplayer online counterterrorism intelligence game. In most

ELICIT experiments, participants play the game through a Web interface and interact with one another solely through textual information exchange. This mirrors in large part the network-centric environment associated with most counterterrorism intelligence work in practice. However, we argue that a more immersive virtual environment offers potential to improve performance. The research described in this article addresses the preliminary design and prototyping of an immersive and dynamic, virtual environment for ELICIT experimentation, in which participants play the game through avatars representing them. We summarize a number of alternate virtual environment platforms available to researchers for work such as this, and we explain the rationale for the specific environment selected for this project. Additionally, we describe the prototypical design strategies for adapting game play into virtual environments and characterize preliminary case examples to understand the differences and potential benefits of adapting ELICIT game play. This research lays a foundation for moving experimentation into immersive virtual environments.

REFERENCES

Alberts, D. S., & Hayes, R. E. (2003). *Power to the edge : Command and control in the information age*. Washington, DC: Command and Control Research Program.

Alexander, C. (1977). *A pattern language*. New York: Oxford University Press.

Beersma, B., Hollenbeck, J. R., Humphrey, S. E., Moon, H., Conlon, D. E., & Ilgen, D. R. (2003). Cooperation, competition, and team performance: Toward a contingency approach. *Academy of Management Journal, 46*(5), 572-590.

Bell, M. W. (2008). Toward a definition of “Virtual worlds”. *Journal of Virtual Worlds Research, 1*(1)

Bergin, R. D., Adams, A. A., Andraus, R., Hudgens, B. J., Lee, J. G., & Nissen, M. E. (2010). Command and control in virtual environments: Laboratory experimentation to compare virtual with physical. Santa Monica, CA.

Elliott, D., Helsen, W. F., & Chua, R. (2001). A century later: Woodworth's (1899) two-

component model of goal directed aiming. *Psychological Bulletin*, *127*(3), 342-357.

Gateau, J. B., Leweling, T. A., Looney, J. P., & Nissen, M. E. (2007). Hypothesis testing of edge organizations: Modeling the C2 organization design space. *Proceedings International Command & Control Research & Technology Symposium*, Newport, RI.

Guzzo, R. A., & Dickson, M. W. (1996). Teams in organizations: Recent research on performance and effectiveness. *Annual Review of Psychology*, *47*(1), 307.

Hudson, K., Wood, N., Wetsch, L., & Solomon, M. (2009). From interactive to immersive: Advertising education takes a virtual leap of faith.*13*(1)

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2008). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual* No. Technical Report A-8). University of Florida, Gainesville, FL:

Leweling, T. A., & Nissen, M. E. (2007). Hypothesis testing of edge organizations: Laboratory experimentation using the ELICIT multiplayer intelligence game. *Proceedings International Command & Control Research & Technology Symposium*, Newport, RI.

Meyer, D. E., Irwin, D. E., Osman, A. M., & Kounios, J. (1998). The dynamics of cognition and action: Mental processes inferred from time-accuracy decomposition. *Psychological Review*, *95*, 183-237.

Nissen, M. E. (2005). Hypothesis testing of edge organizations: Specifying computational C2 models for experimentation. *Proceedings International Command & Control Research*

Symposium, McLean, VA.

Orr, R. J., & Nissen, M. E. (2006). Computational experimentation on C2 models. *Proceedings International Command and Control Research and Technology Symposium,* Cambridge, UK.

Parity Communications Inc. (2006). *Experiments in command and control within edge organizations: Final report* No. EBR06-0002). Boston, MA:

Plamondon, R., & Alimi, A. M. (1997). Time/Accuracy trade-offs in target-directed movements. *Behavioral and Brain Sciences, 20*, 279-303.

Powley, E. H., & Nissen, M. E. (2009). Trust-mistrust as a design contingency: Laboratory experimentation in a counterterrorism context. Washington, DC.

Robbins, S. (2010). *Incommensurate wor(l)ds: Epistemic rhetoric and faceted classification of communication mechanics in virtual worlds.* Unpublished PhD, Ball State University,

Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology, 124*, 207-231.

Scroeder, R. (2008). Defining virtual worlds and virtual environmentsv. *Journal of Virtual Worlds Research, 1*(1)

Thunholm, P., Ng, E. C., Cheah, M., Tan, K. Y., Chua, N., & Chua, C. L. (2009). Exploring alternative edge versus hierarchy C2 organizations using the ELICIT platform with

configurable chat system. *International C2 Journal, 3*(2), 1-51.

Wilson, R. K. (2005). Anger, fairness and What's in the brain, paper prepared for delivery at the festschrift in honor of elinor ostrom. Bloomington, IN.

Wynn, D. M., Ruddy, M., & Nissen, M. E. (2010). Command and control in virtual environments: Tailoring software agents to emulate specific people. Santa Monica, CA.